MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2022/2023 (TERM ID 2230)

ETM3086 – MOBILE AND SATELLITE COMMUNICATIONS

(TE)

2 OCTOBER 2023
2.30 P.M. – 4.30 P.M.
(2 Hours)

INSTRUCTION TO STUDENT

1. This question paper consists of 7 pages including the cover page with 4 Questions only.

2. Attempt **ALL FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided.

Question 1

(a) Given that a total of 33MHz of bandwidth is allocated to a particular FDD cellular telephone system which uses two 25 kHz simplex channels to provide full duplex voice and control channel. Calculate number of channels available per cell if a system uses seven-cell reuse and 12-cell reuse.

[6 marks]

(b) Handoff is one of the important mechanisms for deployment of cellular system.

(i) Briefly explain the handoff process in cellular system.

[2 marks]

(ii) How do system designers specify an optimum signal to initiate the handoff? Draw the average received signal level and indicate which level the handoff should start if the communication occurs from point A to point B as shown in Figure Q1.

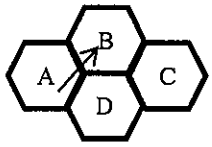

Figure Q1

[2+4 marks]

(iii) What will happen if the handoff threshold level is set very near to the minimum level to maintain a call?

[2 marks]

(c) Techniques such as cell splitting and sectoring are used in practice to expand the capacity of cellular systems.

(i) List **TWO** effects of cell sectoring.

[2 marks]

(ii) Calculate the signal-to-interference ratio (S/I) for a 7-cell repeating pattern, given that path loss exponent, n equal to 3 and 6 first tier co-channel cells are used. If sectoring is applied in such a way the antenna covers 120°, find the S/I improvement.

[3+4 marks]

Continued...

Question 2

(a) Modeling the radio channel has been one of the most difficult parts of mobile radio system design.
   (i) Discuss the importance of path loss prediction model.
   (ii) Explain the difference between large scale and small-scale propagation models.
   (iii) State four different types of small-scale fading.

[2 + 6 + 4 marks]

(b) The received radio signal -100dBm when the height of the base station is 100m. To increase power received from -100dBm to -80dBm, what is the appropriate based station antenna height?

[7 marks]

(c) A base station has a 900MHz transmitter and a vehicle is moving at 80km/h. Compute the received carrier frequency if the vehicle is moving
   (i) Directly towards the base station.

[4 marks]

   (ii) Directly away from the base station.

[2 marks]

Question 3

(a) Briefly explain two orbital effects on satellite communication systems.

[6 marks]

(b) The earth rotates once in a sidereal day and a geostationary satellite must have the same orbital period. Consider a satellite in a circular orbit in the equatorial plane with a period of 23 hours and 50 minutes. Find,
   (i) The radius of the satellite orbit.

[4 marks]

   (ii) The angular drift of the satellite around its orbit per sidereal day, measured at the earth center.

[3 marks]

   (iii) The direction of the drift – towards the east or towards the west.

[2 marks]

(c) Describe the differences between the low earth orbit (LEO) and the highly elliptical orbit (HEO) on these aspects:
   (i) Path loss
   (ii) Propagation delay
   (ii) Spectrum reuse efficiency
   (iii) Duration of satellite visibility
   (iv) Signal strength variation

[10 marks]

Continued...

Question 4

(a) In link budget calculations, we need to provide some allowances for the input and output back off values. Describe input and output back off in satellite communication system.

[6 marks]

(b) An earth satellite ground receiver has an antenna with a gain of 38 dBi and noise temperature of 80 K. The antenna feeds a preamplifier with an effective input noise temperature of 110 K and a gain of 30 dB. The preamplifier is followed by an amplifier with a noise figure of 12 dB and a gain of 50 dB. The transmission bandwidth is 10 MHz. The satellite has an antenna with a gain of 10 dBi and the free space loss is 210 dB. Calculate the followings:

(i) Effective input noise temperature of the earth satellite ground receiver.

[3 marks]

(ii) Average thermal noise power at the earth satellite ground receiver.

[3 marks]

(iii) Minimum satellite transmission power required to achieve a 25 dB SNR at the receiver output of the earth station.

[3 marks]

(c) A geo-stationary satellite is at a distance of 40,000 km from a ground station on earth. The satellite transmits a signal of power 5 W at a frequency of 5 GHz. The satellite antenna gain amounts to 20 dBi:

(i) Calculate the effective isotropic radiated power (EIRP).

[2 marks]

(ii) Calculate the free space loss between satellite and ground station.

[3 marks]

(iii) If the ground station is equipped with a dish antenna, what should be the size of the dish antenna diameter in order the received power to be -120 dBW assuming the efficiency of the receiving antenna, $\eta = 0.56$?

[5 marks]

Continued...

Appendix I: Constant values

Gravitation parameter, μ	=	3.986×10^{14} m^3/s^2
Mean Earth radius, R_E	=	6378 km
Speed of light, c	=	3×10^{8} m/s
Sidereal day	=	23h 56m 4.09s
Boltzmann constant, k	=	1.38×10^{-23} J/K = -228.6 dBW/Hz K

Appendix II: Table of Complementary Error Function

$$erfc(z)=\frac{2}{\sqrt{\pi}}\int_z^{\infty} e^{-t^2}\,dt \quad \text{for } 0\le z\le 3.99 \text{ in steps of } 0.01$$

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	1.000E+00	9.887E-01	9.774E-01	9.662E-01	9.549E-01	9.436E-01	9.324E-01	9.211E-01	9.099E-01	8.987E-01
0.1	8.875E-01	8.764E-01	8.652E-01	8.541E-01	8.431E-01	8.320E-01	8.210E-01	8.100E-01	7.991E-01	7.882E-01
0.2	7.773E-01	7.665E-01	7.557E-01	7.450E-01	7.343E-01	7.237E-01	7.131E-01	7.026E-01	6.921E-01	6.817E-01
0.3	6.714E-01	6.611E-01	6.509E-01	6.407E-01	6.306E-01	6.206E-01	6.107E-01	6.008E-01	5.910E-01	5.813E-01
0.4	5.716E-01	5.620E-01	5.525E-01	5.431E-01	5.338E-01	5.245E-01	5.153E-01	5.063E-01	4.973E-01	4.883E-01
0.5	4.795E-01	4.708E-01	4.621E-01	4.535E-01	4.451E-01	4.367E-01	4.284E-01	4.202E-01	4.121E-01	4.041E-01
0.6	3.961E-01	3.883E-01	3.806E-01	3.730E-01	3.654E-01	3.580E-01	3.506E-01	3.434E-01	3.362E-01	3.292E-01
0.7	3.222E-01	3.153E-01	3.086E-01	3.019E-01	2.953E-01	2.888E-01	2.825E-01	2.762E-01	2.700E-01	2.639E-01
0.8	2.579E-01	2.520E-01	2.462E-01	2.405E-01	2.349E-01	2.293E-01	2.239E-01	2.186E-01	2.133E-01	2.082E-01
0.9	2.031E-01	1.981E-01	1.932E-01	1.884E-01	1.837E-01	1.791E-01	1.746E-01	1.701E-01	1.658E-01	1.615E-01
1.0	1.573E-01	1.532E-01	1.492E-01	1.452E-01	1.414E-01	1.376E-01	1.339E-01	1.302E-01	1.267E-01	1.232E-01
1.1	1.198E-01	1.165E-01	1.132E-01	1.100E-01	1.069E-01	1.039E-01	1.009E-01	9.800E-02	9.516E-02	9.239E-02
1.2	8.969E-02	8.704E-02	8.447E-02	8.195E-02	7.949E-02	7.710E-02	7.476E-02	7.249E-02	7.027E-02	6.810E-02
1.3	6.599E-02	6.394E-02	6.193E-02	5.998E-02	5.809E-02	5.624E-02	5.444E-02	5.269E-02	5.098E-02	4.933E-02
1.4	4.771E-02	4.615E-02	4.462E-02	4.314E-02	4.170E-02	4.030E-02	3.895E-02	3.763E-02	3.635E-02	3.510E-02
1.5	3.389E-02	3.272E-02	3.159E-02	3.048E-02	2.941E-02	2.838E-02	2.737E-02	2.640E-02	2.545E-02	2.454E-02
1.6	2.365E-02	2.279E-02	2.196E-02	2.116E-02	2.038E-02	1.962E-02	1.890E-02	1.819E-02	1.751E-02	1.685E-02
1.7	1.621E-02	1.559E-02	1.500E-02	1.442E-02	1.387E-02	1.333E-02	1.281E-02	1.231E-02	1.183E-02	1.136E-02
1.8	1.091E-02	1.048E-02	1.006E-02	9.653E-03	9.264E-03	8.889E-03	8.528E-03	8.179E-03	7.844E-03	7.521E-03
1.9	7.210E-03	6.910E-03	6.622E-03	6.344E-03	6.077E-03	5.821E-03	5.574E-03	5.336E-03	5.108E-03	4.889E-03
2.0	4.678E-03	4.475E-03	4.281E-03	4.094E-03	3.914E-03	3.742E-03	3.577E-03	3.418E-03	3.266E-03	3.120E-03
2.1	2.979E-03	2.845E-03	2.716E-03	2.593E-03	2.475E-03	2.361E-03	2.253E-03	2.149E-03	2.049E-03	1.954E-03
2.2	1.863E-03	1.776E-03	1.692E-03	1.612E-03	1.536E-03	1.463E-03	1.393E-03	1.326E-03	1.262E-03	1.201E-03
2.3	1.143E-03	1.088E-03	1.034E-03	9.838E-04	9.354E-04	8.893E-04	8.452E-04	8.032E-04	7.631E-04	7.249E-04
2.4	6.885E-04	6.538E-04	6.207E-04	5.892E-04	5.592E-04	5.306E-04	5.034E-04	4.774E-04	4.528E-04	4.293E-04
2.5	4.070E-04	3.857E-04	3.655E-04	3.463E-04	3.280E-04	3.107E-04	2.942E-04	2.785E-04	2.636E-04	2.495E-04
2.6	2.360E-04	2.233E-04	2.112E-04	1.997E-04	1.888E-04	1.785E-04	1.687E-04	1.594E-04	1.506E-04	1.422E-04
2.7	1.343E-04	1.268E-04	1.197E-04	1.130E-04	1.066E-04	1.006E-04	9.492E-05	8.952E-05	8.441E-05	7.958E-05
2.8	7.501E-05	7.069E-05	6.661E-05	6.275E-05	5.910E-05	5.566E-05	5.240E-05	4.933E-05	4.642E-05	4.368E-05
2.9	4.110E-05	3.866E-05	3.635E-05	3.418E-05	3.213E-05	3.020E-05	2.838E-05	2.667E-05	2.505E-05	2.353E-05
3.0	2.209E-05	2.074E-05	1.947E-05	1.827E-05	1.714E-05	1.608E-05	1.508E-05	1.414E-05	1.326E-05	1.243E-05
3.1	1.165E-05	1.092E-05	1.023E-05	9.578E-06	8.970E-06	8.398E-06	7.862E-06	7.358E-06	6.885E-06	6.442E-06
3.2	6.026E-06	5.635E-06	5.269E-06	4.926E-06	4.604E-06	4.303E-06	4.020E-06	3.755E-06	3.507E-06	3.275E-06
3.3	3.058E-06	2.854E-06	2.664E-06	2.485E-06	2.319E-06	2.162E-06	2.017E-06	1.880E-06	1.753E-06	1.633E-06
3.4	1.522E-06	1.418E-06	1.321E-06	1.230E-06	1.145E-06	1.066E-06	9.922E-07	9.233E-07	8.590E-07	7.990E-07
3.5	7.431E-07	6.910E-07	6.423E-07	5.970E-07	5.548E-07	5.155E-07	4.788E-07	4.447E-07	4.130E-07	3.834E-07
3.6	3.559E-07	3.303E-07	3.064E-07	2.843E-07	2.636E-07	2.445E-07	2.267E-07	2.101E-07	1.947E-07	1.804E-07
3.7	1.672E-07	1.548E-07	1.434E-07	1.327E-07	1.229E-07	1.137E-07	1.052E-07	9.736E-08	9.005E-08	8.328E-08
3.8	7.700E-08	7.119E-08	6.579E-08	6.080E-08	5.617E-08	5.189E-08	4.792E-08	4.425E-08	4.085E-08	3.770E-08
3.9	3.479E-08	3.210E-08	2.961E-08	2.731E-08	2.518E-08	2.322E-08	2.140E-08	1.972E-08	1.817E-08	1.674E-08

Note: 1.000E-01 = 1.000×10^{-1}

For $z > 4$, $\quad erfc(z)\approx\frac{1}{\sqrt{\pi}}\left(\frac{e^{-z^2}}{z}\right)$

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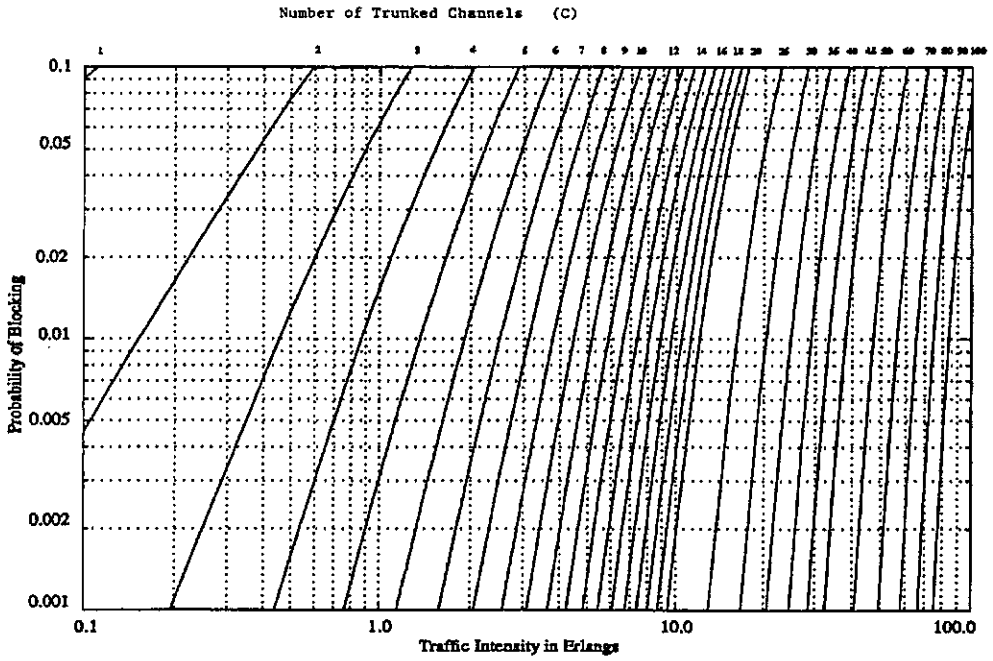
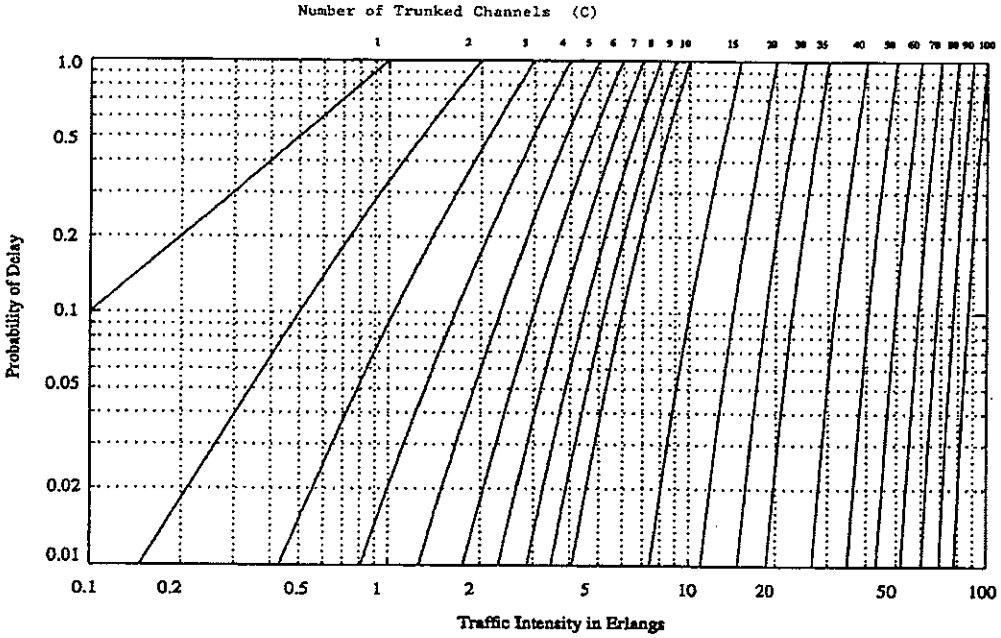
Appendix III: Erlang B and Erlang C Chart



The Erlang B chart showing the probability of blockings as functions of the number of channels and traffic intensity in Erlangs.



The Erlang C chart showing the probability of a call being delayed as a function of the number of channels and traffic intensity in Erlangs.

Continued...

Appendix IV: Formulae

Remarks: The general formulae below may need to be modified according to the context.

Antenna

Effective isotropic radiated power, $EIRP = P_t G_t$

Power flux density, $\phi = \dfrac{EIRP}{4\pi R^2}$

Received power, $P_r = \phi A_{eff}$

Antenna gain of a circular aperture or reflector of diameter D:

$$G_{\max} = \left(\frac{4\pi}{\lambda^2}\right) A_{eff} = \eta\left(\frac{\pi D}{\lambda}\right)^2 = \eta\left(\frac{70\pi}{\theta_{3dB}}\right)^2, \text{ where } \theta_{3dB} = 70\left(\frac{\lambda}{D}\right)$$

Link Analysis

Received power, $[P_r] = [EIRP] + [G_r] - [L_{Total}]$

Free space loss, $L_{FS} = \left(\dfrac{4\pi R}{\lambda}\right)^2$

Noise power spectral density, $N_o = kT$

Noise factor, $F = 1 + \dfrac{T_e}{T_o}$

System noise temperature with reference to the antenna output,

$$T_S = T_{ant} + T_{e1} + \frac{T_{e2}}{G_1} + \frac{T_{e3}}{G_1 G_2} + \ldots + \frac{T_{en}}{G_1 G_2 \ldots G_{n-1}}$$

FDM-FM-FDMA Satellite System

Signal bandwidth, $B = 2(gl\Delta f_{rms} + f_{max})$

where $\log_{10} l = \begin{cases} (-1 + 4\log_{10} n)/20, & n \le 240 \\ (-15 + 10\log_{10} n)/20, & n > 240 \end{cases}$

Relationship between *C/N* and *S/N* is given by:

$$\frac{C}{N} = \left(\frac{S}{N}\right)\left(\frac{b}{B}\right)\left(\frac{f_{\max}}{\Delta f_{rms}}\right)^2 \frac{1}{pw}$$

End of Paper